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AN EVALUATION OF RADIATION-PROCESSED FOODS FOR MILITARY RATIONS*

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In the fall of 1960 a research group from our organization (then known as ORO) was asked to investigate the possible operational, logistical, and economic advantages to the armed forces of employing radiation-processed foods in the military feeding system and to provide a basis to assist the Army in making decisions on the irradiated-food research program.

The preservation of food by sterilization with ionizing radiation is a relatively new concept and at that time had not been attempted commercially. Experimentally, many foods have been irradiated to determine the value, safety, and efficacy of such processing. Various radiation doses have been employed under different conditions of exposure and of associated treatment techniques. The ultimate goal is the attainment of a process that would safely, and at a reasonable cost, preserve foods so that they could be stored in a fresh-like and wholesome condition for long periods of time without refrigeration. Because meats are the highest-valued items in military rations, special research efforts have been placed on the development of radiation-processed meat items for ration components.

Considerable progress has been made since The Quartermaster General's extensive research program on irradiated foods began in 1953. However, their plans for the construction and operation of a developmental pilot plant were indefinitely suspended on the recommendation of the Director of Research and Development of the Army, in 1959. This action was taken partly because of the uncertainty of the wholesomeness of the foods, but mainly on the basis of need for adequate reliable information concerning the operational, logistical, and economic advantages that would justify the use of irradiated foods in military rations and the construction and operation of a pilot plant. In March 1960, a revised Army program on radiation preservation of foods was approved for wholesomeness studies and fundamental research toward development of

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*The data presented in this paper have been published in greater detail as ORO-SP-174, "Radiation-Processed Foods as a Component of the Armed Forces Feeding Systems," August 1961.

end items. The Operations Research study, undertaken by RAC, was included in the plan of that new program.

Our investigation began with an analysis of the technological status of radiation-preservation of foods and the additional research effort needed to attain fully acceptable products for incorporation into military rations during the 1965-1975 time frame. Attention was given to various concepts of military feeding and the tactical operational requirements of various armed-forces units for ration support. Then particular consideration was given to the logistical implications involved in the integration of irradiated components in military rations, including savings in manpower, storage, equipment and supplies. The costs of processing, storing and transporting irradiated foods were concurrently studied and our estimates compared with estimated costs of the freeze-dehydration process, and the costs of the commercial canning and freezing processes.

An examination was also made of the different types of radiation sources that could be used for processing foods, and of the availability, costs, and efficiency of these radiation sources.

As a last step, we investigated the feasibility of establishing a mobilization base containing irradiated meats as ration components, and estimated the number and cost of accelerators needed for a production base.

Our findings were published in August of last year.

In order to be approved by the Food and Drug Administration, irradiated foods for public consumption must not show radioactivity levels that are distinguishable from background. Reports have shown that foods can be processed by gamma radiation from Co^{60} or by electron accelerators below energy levels of 10 Mev without inducing measurable radioactivity in the foods. Radiation preservation of meats requires an exposure dose of about 4.5 megarads preceded by short heating to an internal temperature of about 160° F. Reports showed that beef and pork processed this way had remained acceptable for at least 25 months at 70°F storage temperature and for 16 months at 100°F. Bacon and ham had been stored about one year and chicken for one and one-half years with good acceptability.

We found that numerous, extensive studies to determine the wholesomeness of irradiated foods had been conducted, both in-house and under contract to the Army Quartermaster Corps and the Surgeon General.

Objective analyses of the results of these studies, including long-term animal feeding tests, showed no harmful effects attributable to radiation processing beyond correctable vitamin loss. However, prudently cautious recommendations by the Surgeon General included a few more years of research for completion of the wholesomeness study program.

In the future feeding concept shown in Fig. 1, single meal modules would be employed as follows:

(a) The 25-in-1 uncooked meal might be used behind the contact area. This ration will contain canned, dehydrated, and irradiated foods, and will be served by trained food service personnel in a unit-mess type of feeding.

(b) From the reserve area forward into the contact area the 25-in-1 precooked quick-serve meal would be used where the tactical situation precludes the preparation and serving of the 25-in-1 uncooked meal. This ration will contain precooked freeze-dehydrated foods as the major component, which will be prepared by one or two individuals by pouring hot water directly into the food packages and serving it on disposable trays packed in the carton with the meal. Trained food service personnel would not ordinarily be involved. Under some circumstances precooked irradiated meats might be used in place of freeze-dehydrated meats.

(c) In situations where small groups are dispersed from their units for long periods, the 6-in-1 precooked ready-to-serve meal would be used. It will contain the same type of foods as the 25-in-1 meal.

(d) In the contact area especially and under certain conditions to the rear, the tactical situation will often require the use of an individual ready-to-eat meal. This will contain precooked irradiated foods that will normally be eaten cold but could be warmed by the individual when his situation will allow it. Flexible packaging will add to the value of this ration.

(e) Individuals would also be issued an individual combat food packet for emergency use. This will be a small, compressed, high-caloriccontent food item totalling about 1000 calories. This is not intended to replace a meal when other rations can be provided but is to be capable of sustaining a man for as long as 2 to 10 days under emergency situations without appreciable loss of efficiency and without irreversible physiological damage.

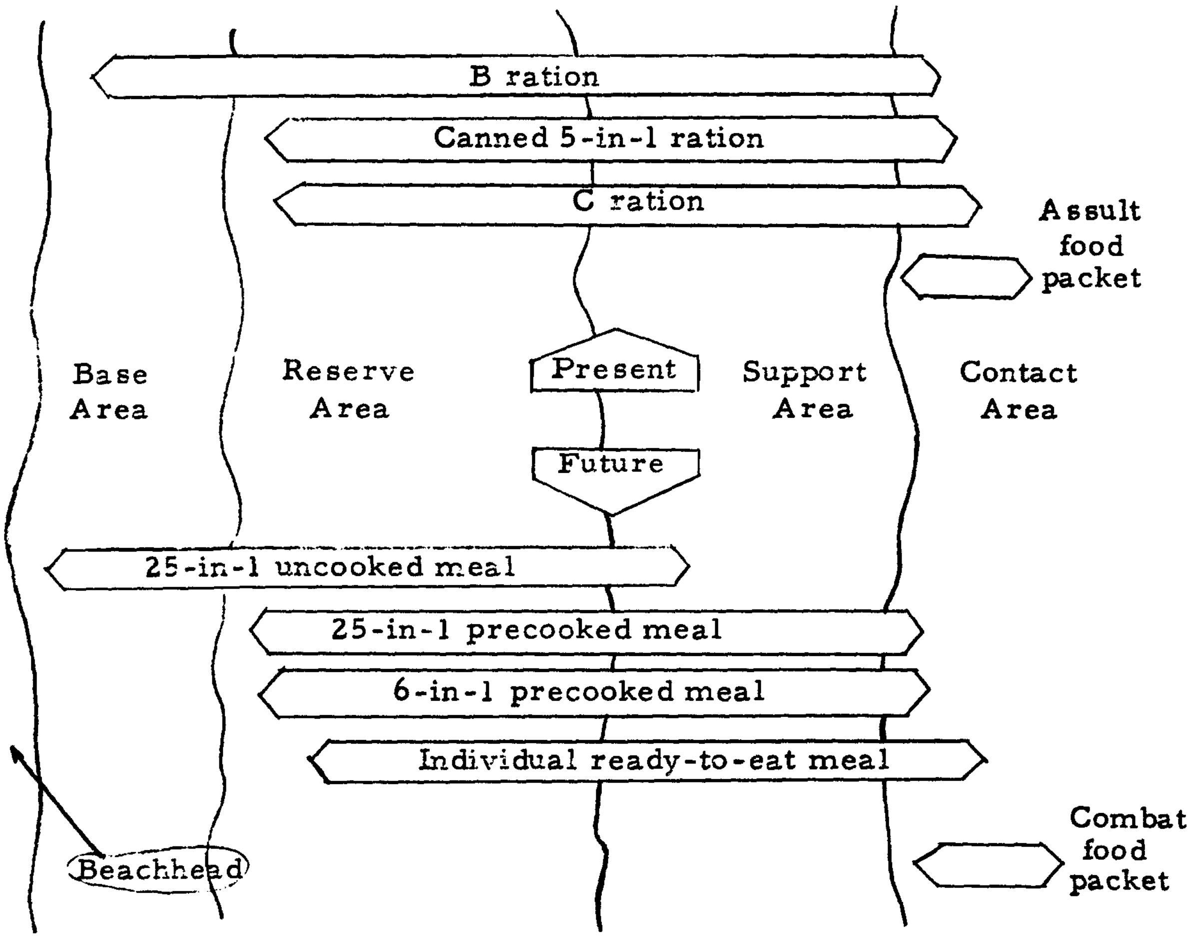

Fig. 1 -- Present and Future Feeding Concepts

With the current emphasis on mobility of US forces vs enemy mass a continuing requirement exists for improved logistical operations to support such mobility. This requirement pervades all classes of supply. Although class I supply involves only a small fraction of the tonnage of class III fuels, simplified rations do contribute to reducing fuel consumption as well as equipment and manpower requirements, and to improving mobility.

In seeking a logistical advantage of employing irradiated rations, we estimated the potential savings these rations would permit if the logistic burden of field kitchens could be eliminated from forward units. An Army of 2 million men was considered, using a distribution of men in a theater based on data from FM 101-10, as shown in Tables I and II.

TABLE I

COMPOSITION OF THEATER SLICE BY ASSIGNMENT

Assignment	Troops
Basic division	13,961
Nondivision	18,540
Theater overhead	24,750
Army	(10,750)
Air Force	(14,000)a
Total	57,251

[a] Two Air Force wings including Army support.

TABLE II

COMPOSITION OF AN OVERSEAS ARMY SLICE

Item	Division	Corps[a]	Army (rounded)[b]
Men			
Armor	14,600	14,600	---
Infantry	13,748	41,244	---
Corps, nondivision	---	74,160[c]	---
Theater overhead	---	99,000[d]	---
Total		229,004	687,000
Field Kitchens			
Armor	98	98	---
Infantry	70	237	---
Total		335	1,005
Bakery companies (mobile)	---	---	5
Refrigeration companies (mobile)	---	---	1

[a]Corps has three infantry divisions and one armored division plus non-division troops.

[b]Army has three corps.

[c]18,540 x 4

[d]24,750 x 4.

In Table III can be seen the requirements for the operation of field kitchens for 2 million men in a theater of operations. Of particular importance is the fuel consumption rate of over 65,000 tons per year.

TABLE III

REQUIREMENTS FOR FIELD KITCHENS
(For 2 million men overseas)

Item	Quantity
No. of field kitchens	2,925[a]
Men	14,625
Trucks	2,925
Water, millions of gal/year	
Equipment	213[c]
Men	80[d]
Total	293
Fuel, tons/year	
Trucks	4,100[e]
Cooking	56,000[f]
Pump water	5,130[g]
Total	65,230

[a]From Table II $(1005 \times (2 \times 10^6)) / 687{,}000 = 2925$ field kitchens.

[b]Based on five men per field kitchen.

[c]Based on 200 gal/day/kitchen for washing and rinsing mess trays plus all else not consumed directly by men.

[d]Based on 15 gal/man/day. Truck water requirements are small in comparison.

[e]Based on 2000 miles/year/truck, average fuel consumption of 5 miles/gal, and 7.0 lb/gal.

[f]Based on 15 gal/day/kitchen.

[g]Based on 1 gal of fuel required to pump 200 gal of water at the water source.

The requirements for mobile bakery companies are shown in Table IV. These companies bake bread for troops in the field, but may also be assigned to supplement the production of garrison bakery units as the situation demands. During overseas use these bakeries require over 8,000 tons per year of fuel per 2 million men.

TABLE IV

REQUIREMENTS FOR MOBILE BAKERY COMPANIES
(for 2 million men overseas)

Item	Quantity
No. of bakery companies	15[a]
Men	2130[b]
Trucks	315[c]
Water, millions of gal/year	
Equipment	39[d]
Men	12[e]
Total	51
Fuel, tons/year	
Trucks	2200[f]
Ovens	1150[g]
Electric generators	3950[h]
Pump water	890[i]
Total	8190

[a]From Table II $(5 \times (2 \times 10^6))/687{,}000 = 14.6$ bakery companies.

[b]Based on 142 men/company.

[c]Based on 21 trucks/company.

[d]Based on 100 gal/hr/platoon and three platoons per company.

[e]Based on 15 gal/man/day. Truck water requirements are small in comparison.

[f]Based on 10,000 miles/year/truck, average fuel consumption of 5 miles/gal, and 7.0 lb/gal.

[g]Based on 10 gal/day/oven and six ovens per company.

[h]Based on three generators (25 Kw each) per company running continuously; specific fuel consumption = 0.6 lb/hp-hr.

[i]Based on 1 gal of fuel required to pump 200 gal of water at the water source.

Mobile refrigeration companies deliver perishable foods from depots to supply points, but many also use their semitrailer vans as fixed refrigerators as the situation demands. During use in the theater of operations, these companies require fuel for gasoline-driven refrigerant compressors and trucks. These requirements are illustrated in Table V.

TABLE V

REQUIREMENTS FOR MOBILE REFRIGERATION COMPANIES
(For 2 million men overseas)

Item	Quantity
No. of refrigeration companies	3[a]
Men	564[b]
Trucks	165[c]
Water for men, millions of gal/year	3[d]
Fuel, tons/year	
Trucks	1,150[e]
Refrigeration equipment	10,600[f]
Pump water	50[g]
Total	11,800

[a]From Table II $(1 \times (2 \times 10^6))/687,000 = 2.9$ refrigeration companies.

[b]Based on 188 men/company.

[c]Based on 55 trucks/company, of which 48 are 7 1/2-ton semi-trailers and 7 are 2 1/2-ton trucks.

[d]Based on 15 gal/man/day. Truck water requirements are small in comparison.

[e]Based on 10,000 mile/year/truck, average fuel consumption of 5 miles/gal, and 7.0 lb./gal for both truck types.

[f]Based on 5-hp motors, specific fuel consumption of 0.6 lb/hp-hr, and 7000 hr/year of operation.

[g]Based on 1 gal of fuel required to pump 200 gal of water at the water source.

If the use of irradiated foods and freeze-dehydrated foods would permit the elimination of refrigerated warehouses, a substantial saving in the overseas logistical effort shown in Table VI could be attained.

TABLE VI

REQUIREMENTS FOR REFRIGERATED WAREHOUSES
(For 2 million men overseas, warehouse size, 20 by 100 ft)

Item	Quantity
No. of refrigerated warehouses	173
Men	519[a]
Water, millions of gal/year	
Equipment	6
Men	3[b]
Total	9
Fuel, tons/year	
Electricity generation	12,700
Pump water	100[c]
Total	12,810

[a]Based on three men per warehouse (ORO estimate).

[b]Based on 15 gal/man/day.

[c]Based on 1 gal of fuel required to pump 200 gal of water at the water source.

Table VII summarizes those requirements for kitchens, bakeries, and refrigeration facilities which could be reduced from the total logistical effort by employment of irradiated foods and dehydrated foods in military rations. Net savings that could be attained in fuel alone are shown in Table VIII. The delivery of bulk fuel by truck is one of the largest problems in theater logistics.

TABLE VII

REQUIREMENTS FOR KITCHENS, BAKERIES, AND REFRIGERATION FACILITIES
(For 2 million men overseas)

Facility	Men	Trucks	Water, millions of gal/year	Fuel tons/year
Field kitchens	14,625	2925	293	65,230
Bakery companies	2,130	315	51	8,190
Refrigeration companies	564	165	3	11,800
Refrigerated warehouses	519	0	9	12,800

TABLE VIII

NET FUEL SAVINGS
(For 2 million men overseas)

Item	Fuels saved, tons/year
Field kitchens	65,230
Bakery companies	8,190
Refrigeration companies	10,600[a]
Refrigerated warehouses	12,700[b]
Total for irradiated foods	96,720[c]
Preparation of freeze-dehydrated food	-5,080[d]
Total for freeze-dehydrated foods	91,640[e]

[a]Refrigerating equipment only.

[b]Refrigerating equipment only. All electricity generation is assumed to be for refrigeration purposes.

[c]Fuel for electricity for truck shops is less than 0.5 percent of this total.

[d]Fuel consumed in heating of water for freeze-dehydrated foods.

[e]Corresponds to 250 tons/day and is not sensitive to the assumed percentage of men who may eat freeze-dehydrated food regularly. For example, 50 percent freeze-dehydrated food in a theater yields 96,720 - 10,160 = 86,560 tons/year, which corresponds to 237 tons/day.

Our cost analysis for processing and transporting irradiated foods showed that these costs were similar and competitive to those of freeze-dehydrated foods and foods preserved by other commercial means.

Our analysis of costs of operation of electron accelerators included the result that the cost of these machines per kilowatt of output power decreases with the increase in the power rating of the accelerator. In addition, at any given radiation dose the output in terms of food processed is proportional. When we applied our operational costs analyses to the problem of establishing a mobilization base, we found that seven 100-Kw accelerators or twelve 30-Kw accelerators would be required to process the total annual meat ration requirements per 1 million men (Fig. 2). The costs of processing this amount of meat is shown in Table IX.

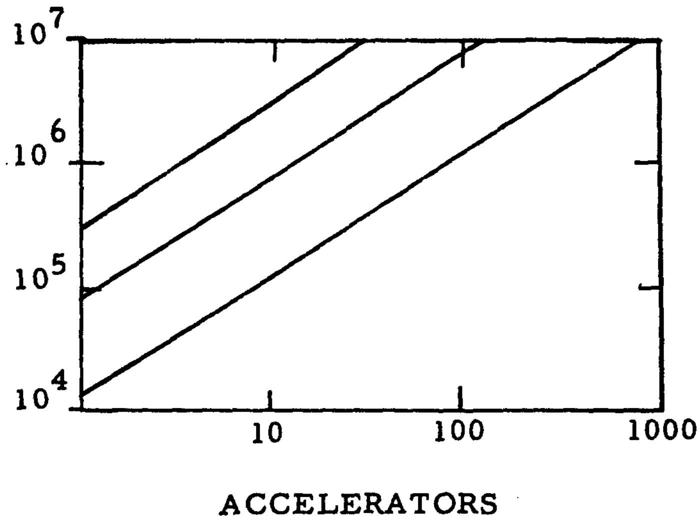

Fig. 2 -- Number of Accelerators Needed to Treat Meats for Armed-Forces Personnel

TABLE IX

ANNUAL CAPITAL AND OPERATING COSTS FOR MEAT PROCESSING
(In millions of dollars)

Manpower level	First Year		Subsequent Years[a]	
	30 Kw	100 Kw	30 Kw	100 Kw
10^4 men	0.039 - 0.057	0.016 - 0.029	0.020	0.010
10^6 men	3.9 - 5.7	1.6 - 2.9	2.0	1.0
10^7 men	39.0 - 57.0	16.0 - 29.0	20.0	10.0

[a]No amortization, operating costs only.

The QMC generally stocks meat reserves in a 15-month supply (composed of a 12-month operational reserve plus a 3-month safety reserve). We determined that a mobilization base reserve of 15 months' rations containing irradiated meat components could be obtained by establishing a production base and operating for one year nine 100-Kw electron accelerators per million men supplied.

About 2 years of total lead time would be required to establish the production base and produce the 15-month reserve supply.

It is likely that only 50% of the meat components of future rations in this system would contain irradiated meats; the rest being processed by other means. Under this consideration the electron accelerators required for the reserve supply would be reduced to 5.

The results of our studies permitted us to make certain conclusions, some of which were as follows:

CONCLUSIONS.

1. The use of rations containing irradiated foods instead of B and C rations and the elimination of field kitchens in general war could result in logistical savings equivalent to 97,000 tons of fuel/year/2 million men in the theater of operations.

2. The logistical savings gained by employing only dehydrated foods instead of B and C rations would be equivalent to 91,000 tons of fuel/year/2 million men.

3. In 1965-1975 irradiated foods could have a distinctive advantage over all other types of foods in providing an operationally suitable individual combat meal that would be well received by fighting men.

4. The estimated cost of radiation processing of foods would be competitive with the costs of the thermal-canning, freezing, and freeze-dehydration processes.

5. About 2 years would be required to obtain a mobilization base composed of a 15-month reserve supply of rations with irradiated meats comprising 50 percent of the meat components. This time includes the estimated 9 to 12 months required to establish radiation facilities and the 12 months required to process the rations.

6. To process the 15-month supply of rations, five 100-Kw accelerators/million men would be required at a cost of $1 million to $1.8 million.